Review: CAFE Compliance and Effects Modeling System

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23 August 2005

General Comments

The CAFE Compliance and Effects Modeling System (CAFE-CEMS) is a tool used to predict the application of efficiency-increasing technologies to specific vehicle models in response to changes in CAFE standards, and to calculate resultant CAFE levels among vehicle manufacturers. CAFE-CEMS also predicts the impacts on employment, energy use, criteria and CO2 emissions, total miles driven, and other monetary and non-monetary externalities from the light-duty vehicle sector subject to, and potentially subject to, changes in CAFE regulations. The system was developed to conduct analysis for rulemakings addressing CAFE reform and for setting standards for model year 2008 light trucks. CAFE-CEMS is also able to conduct analysis of passenger cars.

My comments are based on the CAFE-CEMS model documentation, draft 5/4/05, accompanying input spreadsheets (demo_marketdata_042805, demo_parameters_042805, demo_scenarios_042805, demo_technologies_042805), associated output spreadsheets, and occasional electronic communications from Carol Hammel-Smith (NHTSA) clarifying CAFE-CEMS's state of development. I have not examined the implementation of CAFE-CEMS's algorithms and logic in the computer source code.

Given its specific and broad objectives, the CAFE-CEMS model necessarily incorporates data and assumptions about technologies, economic analysis, energy use and emissions of the light-duty vehicle sector. In general, CAFE-CEMS's applied economic modeling and assumptions appear reasonable for its intended purposes. Lack of complete precision in the model documentation creates some ambiguity for interpretation. I indicate below general and specific suggestions for improvement of CAFE-CEMS and its documentation. I also list a number of questions.

One area that should be further addressed is technology cost and fuel use uncertainty. CAFE-CEMS appropriately incorporates the range of fuel savings and technology costs from the NRC's CAFE report by using low, average and high parameter estimates. For any given model run these are set from the options menu. For example, the user could select low technology costs and high fuel use. The model is then run and technologies are chosen according to the algorithms in the model and the resultant model outputs are produced. What would be superior is an automated process that picks from, perhaps, two independent, uniform probability distributions of technology cost and fuel consumption estimates. This could be done for all or a sub-set of the parameters. If CAFE-CEMS were then run repeatedly, perhaps several hundred to one-thousand times, this would produce a

much fuller range of interactions of technology cost and performance. This process would highlight which input assumptions are the most important for the model's chosen technologies and resultant outputs. Additional work could then be focused on reducing the uncertainty in those highlighted input assumptions. This addition would enhance the robustness CAFE-CEMS's predictions of technology adoption and resultant fuel consumption, energy use, emissions and other impacts.

Specific Comments
Compliance Simulation and Technology Application

1. Please comment on the "engineering conditions" that we employed (Table 3 in documentation) to constrain the applicability of various technologies. My comments refer to Table 4.

A. Strict engineering assessments are not my strength as a reviewer.

2. Please review and comment on the logic (Figure 3, Figure 4, and surrounding text in documentation) we have developed to simulate the application of technologies in response to CAFE standards.

A. The logic developed to simulate the application of technologies to each vehicle model, engine, and transmission (as described in the text and shown in Figures 3 and 4) appears appropriate and reasonable. At times, nonetheless, the logic is difficult to follow. I describe this ambiguity in more detail below.

B. The logic of CAFE-CEMS is difficult to follow in places. It would help for a more detailed statement of CAFE-CEMS's equations with precise use of subscripts indicating sets and subsets. In particular from the text and general equations, CAFE-CEMS's primary objective is, for each manufacturer, *F*, to minimize the discounted sum of effective costs, cafe fines, credit sales/purchases and technology costs. This should be written out in full. For manufacturer *F*, this would look something like this:

$$Minimize \quad OBJ_F = \sum_{t=1}^{t=T} \sum_j \frac{1}{(1+r)^t} \sum_i \left(\frac{\Delta TECHCOST_j + \Delta FINE_i - VALUE_{FUEL_j}}{Nj} \right) N_i \quad (1.1)$$

Where:

$$Fine = -k_F [.], \quad (1.2)$$

For example, consider Equation 1.1 in the documentation:

$$Cost_{eff} = \left(\frac{\Delta TECHCOST + \Delta FINE - VALUE_{FUEL}}{Nj} \right). \quad (1.3)$$

In the text, we are told that $\Delta FINE$ is defined (appropriately so) only for a subset of j of all vehicles i that could use technology k. Thus, a clearer statement for evaluating technology k equation 1.1 is:

$$Cost_{eff,i} = \left(\frac{\Delta TECHCOST_j + \Delta FINE_i - VALUE_{FUEL_j}}{Nj} \right) \quad \forall\, k \in i. \qquad (1.4)$$

C. Secondly, it would also be helpful if there were a new table listing all variables, set definitions and symbols used throughout the documentation. A couple of cases highlight the issue. On p. 16, l. 16, we see language "vehicle i," where as on p. 16, l. 24 we see "model i." Are model and vehicle the same thing? Additionally, p. 16. l. 25 we see *v* used to indicate an incremental year to model year MV, but on p. 20, l. 28, we see *t* used to increment MV. Are *t* and *v* the same index?

A table like this would be helpful.

Name	**Definition**	**Range/subset**	**Units**
i	model	$i \subseteq j$	
j	cohort class	$j \in J$	
$Cost_{eff}$	effective cost of new technology		\$/vehicle
$Credit_c$	CAFE credits		vehicles *m/g
Etc.			

D. Figures 3 & 4. How do Figures 3 and 4 interact? Is Figure 3 nested in Figure 4 or the reverse?

E. In equation 1.2 I don't understand the rationale for adding 0.5 to v in the discount term $\frac{1}{(1+r)^{v+0.5}}$. This needs to be justified or modified.

F. It is unclear to me how the application of Best Next technologies interacts with potential vehicle sales mix changes as an alternative compliance strategy.

G. As an alternative modeling approach to the one used here, the logical test at the top of Figure 3 could be to minimize $COST_{eff}$ rather than Fines Required. This would allow for a later expansion of CAFE-CEMS to allow for across manufacturer credit trading. The logical test of Fines Compliance and willingness to pay fines would come after a manufacturer applies the Best Next technology that is cost effective.

H. Figure 4. Determination of …Applications. There appears to be a logical error in decision box: "Can pending technologies still be applied to some vehicles?" There are two paths to enter this test, but there is only one exit: "yes", which then evaluates

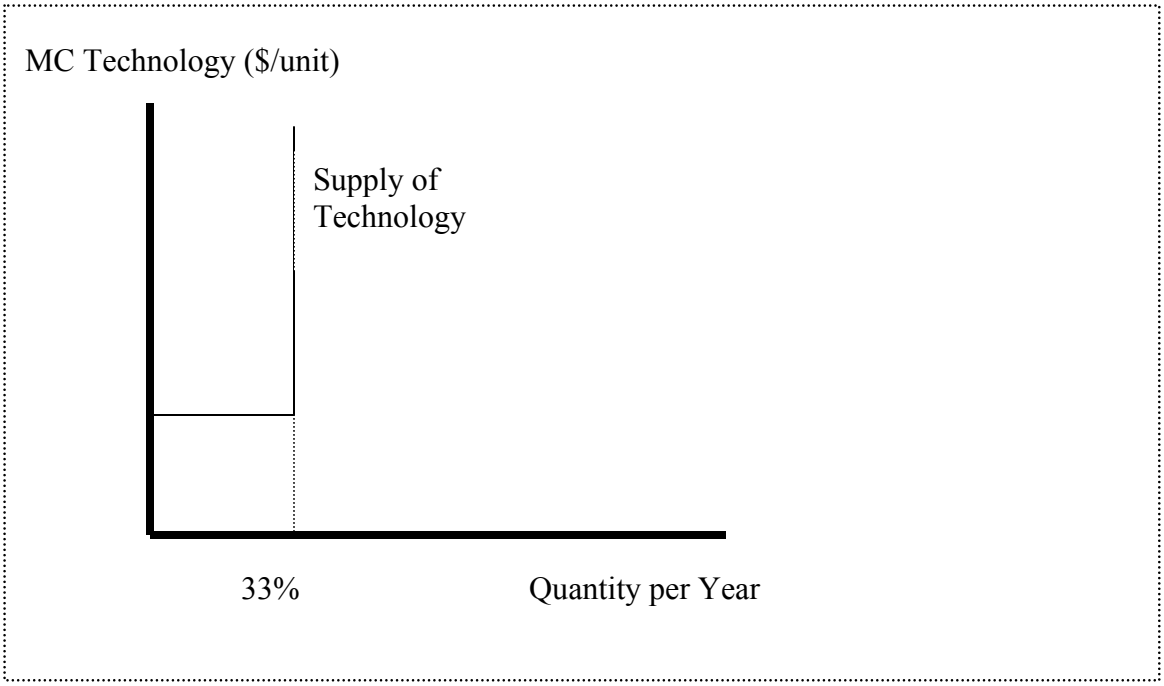
potential applications of pending technologies. It would seem that this decision box should have a "no" choice.

I. Figures 3 & 4. I am concerned about possibility for the non-minimization of costs and non-optimal technology choice arising from path dependency in the solution algorithm. The text (p. 19) after Figure 4 states: "Within a given technology group, the algorithm considers technologies in the order in which they appear." It appears from Figure 3 that one could find that the most cost effective technology would be from, for example, the Accessory Load Reduction set. This would then be applied; next a technology from Transmission Modification would be best, and so on. However, it might be true, that an alternative path would yield lower costs when considered as a whole. What steps have CAFE-CEMS's developers taken to guard against this possibility? Has the order of technologies in each technology group been arranged to prevent this? Is there a way to explore alternative paths via slight changes in technologies' costs or applicability assumptions? Given the number of technologies (and the cheapness of computing power) a global search algorithm that examined all feasible combinations of technologies may be tractable.

J. P. 20, eq. 1.14 Although it may work, it seems a bit awkward to define *new* vehicles of model *k* produced in model year *MY* as $n_{k,MY}$ and then define the number of vehicles of model k produced in MY still surviving in year future year t as $n_{k,MY,t.}$ A cleaner way to define both concepts is to use $n_{k,MY,t}$ with the convention that for new vehicles t=0 or 1 (as per footnote 33).

3. Please review and comment on our input assumptions (Table C-5 and similar) regarding the applicability, cost, and effectiveness of different technologies.

A. CAFE-CEMS's authors have chosen a practical way to address the very important and difficult issue of how to constrain the introduction of the rate at which new technologies can penetrate the fleet. In particular they have chosen to model the supply curve as horizontal (constant unit costs) with a vertical kink or limit. The example below shows the kink with a 33% phase in limit.



This is a reasonable approximation given that the limits are correctly set. I am unable to comment on the engineering considerations concerning the specific limits employed in CAFE-CEMS.

Ideally, CAFE-CEMS would allow greater levels of penetration per year at an increased (i.e., non-constant) cost per unit. This would reflect such real-world considerations such as having to pay overtime to run assembly plants at more intense levels or earlier retirement and replacement of capital equipment. Benchmarking upward-sloping technology cost curves, and accounting for a more rapid turnover in capital equipment, may or may not be feasible depending on the availability of data at the manufacturing plant level.

4. Have we thoroughly represented specific technologies? Have we omitted technologies that we should include, or are there others currently included that we should omit? If additional technologies are suggested, what input assumptions should we make regarding applicability, cost, and effectiveness, and what "engineering constraints" should we apply? (pp. C9-C11)

A. CAFE-CEMS has chosen to allow for dieselization. I am concerned that this technology may not be available for use in states certifying to California Air Emission standards.

Cost Allocation

5. Please review and comment on the cost allocation strategies employed. Have we omitted any cost allocation strategies that should be included? (Section II.B.2)?

A. The cost allocation strategy employed in this version of CAFE-CEMS is set at the default "as incurred".

Effects Calculations

6. The system currently employs vehicle survival and mileage accumulation schedules developed by EPA for use in its MOBILE6 vehicle emission factor model (see Appendix C, Table C-17 and surrounding text), and these values vary significantly among different types of vehicles at each age during their expected lifetimes. Are these vehicle survival and use assumptions the most appropriate to employ in analyzing various effects of stricter CAFE standards, or is more reliable information available?

A. On 31 May 05 Carol Hammel-Smith (NHTSA) indicated that the MOBILE6 data have been replaced by similar schedules estimated from odometer-based estimates of annual mileage from the 2001 National Household Transportation Survey. Survival rates used in the model are estimated from R.L. Polk's National Vehicle Population Profile for 1997-2002. These data sources are appropriate.

7. We currently account for the difference between laboratory and on-road fuel economy using a single estimate of on-road mileage shortfall for all vehicle classes and fuel types (Appendix C, p. C26). Should we attempt to identify estimates of this difference that vary among vehicle types or technologies? If not, what adjustment(s) to the current value would be appropriate to apply for vehicles to be sold during model years 2008-2012? (equations 1.2, 1.20, 1.37, Table C- 14)

A. The 15% fuel economy factor presumably comes from study: Hellman, K.H. and J.D. Murrell. 1984. "Development of Adjustment Factors for the EPA City and Highway MPG Values," SAE Technical Paper Series #840496, Society of Automotive Engineers, Warrendale, Pennsylvania. Given that this is somewhat dated, a newer adjustment factor may be appropriate.

B. I note that the "forecast data" spreadsheet for benefit computations uses the on-Road to EPA test MPG ratio of 0.752 (cars) and .820 (trucks). The AEO2005 is given as the reference. This inconsistency should be addressed; the same ratio should be used in both parts of CAFE-CEMS.

8. Please comment on the appropriateness of our input assumptions regarding the following social costs of fuel production and driving: petroleum market externalities, congestion, noise, and accidents. Please identify any estimates of these costs that you feel would be more appropriate to use in assessing the economic benefits from reducing fuel production and use or the economic costs of additional driving. (pp. C27 - C29).

A. CAFE-CEMS generally uses appropriate, mid-range estimates of the social costs of driving as found in the published literature. This includes parameters from the GREET model, MOBILE6, and work by Green, Leiby, and others.

B. P. 26. Why does CAFE-CEMS reduce carbon emission saved by only accounting for fuel refined domestically via the parameter, r? This seems inconsistent with the treatment of carbon emissions from petroleum extraction which ignores the source, domestic or foreign, of the crude oil.

C. P. 27. CAFE-CEMS calculates the increase in criteria emissions from the rebound effect correctly noting that criteria emissions are regulated on a per-mile, as opposed to a per-gallon basis. To the extent that the relationship between fuel use and criteria emissions becomes stronger for mileage greater than emission certification requirements, decreases in fuel use may decrease criteria emissions for high mileage vehicles. Should this offsetting effect be taken into account?

D. A minor point, but one that could help for updating CAFE-CEMS is one of units and conversions. The text notes (p. C-24) that the monopsony cost of oil imports comes from a 1997 study by Leiby et al. A mid-point range for this cost is given as $2.50/barrel. The text and spreadsheet note that this is approximately $0.061 gallon. Simply performing this calculation yields a slightly different answer, $2.50/42 = $0.0595. Similarly, the text also uses a price shock component at $2.00/barrel and states this is equivalent to $0.045 a gallon. Again, performing the calculation yields a slightly different answer, $2.00/42 = $0.0476 gallon.

Another example is given by the discrepancy in the base year dollar convention. Table C-21, "Forecast Data" notes that retail fuel prices are in 2001 dollars, while the "Economic Values" spreadsheet states that prices are in 2003 dollars. Given the current low rates of inflation this is not a serious problem.

My point is to not to identify minor errors of no appreciable importance to CAFE-CEMS's overall results, but to insure consistency and transparency. It might be preferable to create a new spreadsheet with all the primary data in the original units (and dates) and then show, explicitly, in the spreadsheet how the conversions are performed. This may facilitate updating CAFE-CEMS through time and increase overall transparency and accuracy.

E. I may have missed it, but I did not see a discussion of the renewable fuel (e.g., ethanol) content assumption for gasoline. It would seem reasonable to add some additional capacity to CAFE-CEMS to examine the energy and environmental impacts from implementing a national renewable content standard as has been proposed in recent legislation.

Specific Additional Comments

1. p. 2, l. 17. There is small grammar error, "tight the deadlines" should be "the tight deadlines."
2. p.2, l. 19. Is "set no *more* than 18 months" correct or should the statement be, "set no *less* than 18 months?"